BAYOU COCODRIE WATERSHED TMDL
FOR DISSOLVED OXYGEN
INCLUDING WLAS FOR FIVE POINT SOURCE DISCHARGES

SUBSEGMENTS 060101, 060102, 060201, 060202, and 060203

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Prepared for:

Environmental Technology Division
Louisiana Department of Environmental Quality

By:

FTN Associates, Ltd.
3 Innwood Circle, Suite 220
Little Rock, AR 72211

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EXECUTIVE SUMMARY

This report presents the results of a watershed based, calibrated modeling analysis of the Bayou Cocodrie system. The modeling was conducted to establish a dissolved oxygen TMDL for the Bayou Cocodrie watershed. The model extends from the headwaters near Glenmora, LA and Forest Hill, LA to the confluence of Bayou Cocodrie with Bayou Boeuf near Washington, LA. The Bayou Cocodrie system is located in south central Louisiana and its watershed includes the following tributaries: Little Spring Creek, Spring Creek, Hurricane Creek, Bayou Chicot, Choctaw Bayou, and several unnamed tributaries. The watershed is 466 square miles in area. The Bayou Cocodrie system is in the Vermilion-Teche Basin and includes Water Quality Subsegments 060101, 060102, 060201, 060202, and 060203. The area does not include any large cities, and land use is dominated by forests and agriculture. A total of five point source discharges were included in the modeling effort.

Input data for the calibration model was developed from the LDEQ Reference Stream Study; data collected during the 1999 intensive survey; data collected by LDEQ and USGS at several ambient monitoring stations in the watershed; DMRs and permits for each of the point source dischargers; USGS drainage area and low flow publications; concurrent modeling studies being conducted by LDEQ in the area; and data garnered from several previous LDEQ studies on non-point source loadings. A satisfactory calibration was achieved for most of the system. In those cases where the calibration was not as accurate (primarily due to extremely limited data), the difference was in the conservative direction. For the projection models, data was taken from the current discharge permits and ambient temperature records. The Louisiana Total Maximum Daily Load Technical Procedures, 1999, have been followed in this study.

Modeling was limited to low flow scenarios for both the calibration and the projections since the constituent of concern was dissolved oxygen and the available data was limited to low flow conditions. The model used was QUAL-TX, a modified version of QUAL-II. QUAL-TX was selected since it offers the ability to model branched systems and has been used successfully in Louisiana in the past.

The 1996 and 1998 303(d) lists and the Modified Court Ordered 303(d) list cited parts of the Bayou Cocodrie system (WQ Subsegments 060101, 060102, 060201, 060202, and 060203) as being impaired due to organic enrichment/low DO and required the development of Total Maximum Daily Loads (TMDLs) for dissolved oxygen (DO). Subsegments 060102, 060201, 060202, and 060203 are listed in the court ordered document and Subsegments 060102, 060201, and 060203 are listed in the 1998 document. The three subsegments on the 1998 list for organic enrichment/low DO (060102, 060201, and 060203) were ranked priority one.

This TMDL addresses the organic enrichment/low DO impairment. The TMDL for each season is summarized in the following table:

	Allowable oxygen demanding load (lbs/day)		
	Current Summer Criteria	Proposed Summer Criteria	Winter Criteria
Wasteload allocation for point sources	228	432	516
Margin of safety for point sources	60	112	134
Load allocation for manmade NPS	35587	55638	58135
Margin of safety for manmade NPS	3954	6182	6460
Load allocation for natural NPS	118070	126696	65971
Margin of safety for natural NPS	0	0	0
Total maximum daily load	157899	189059	131215

The results of the summer and winter projections show that reductions in oxygen demanding loads are needed for both point sources and nonpoint sources in order for the DO standards to be met in all portions of the Bayou Cocodrie system. The point source upgrades and nonpoint source reductions needed are summarized in the following table:

					Manmade Nonpoint Source Loads		
	City of Glenmora	Village of Forest Hill	Plaquemines Alligator Farm	Lake Chicot State Park WWTP	Bayou Cocodrie	Cocodrie Lake	Bayou Chicot System
Proposed summer criteria*	10/10/20/5.0	10/10/20/2.0	10/5.0/2.5/2.0	30/15/7.5/2.0	50% & 20% **	20%	100%
Current summer criteria*	10/2/4/6.0	10/10/20/2.0	10/5/2.5/6.0	10/10/5/5.0	100%	100%	100%
Winter criteria*	10/10/20/2.0	10/10/20/2.0	10/25/12.5/2.0	30/15/7.5/2.0	0%	0%	100%

* Point source effluent limits are expressed as BOD/NH_3N/Org-N/DO, percentages are averages
** Reductions needed in 2 reaches; most of Bayou Cocodrie required no reductions.

The proposed criteria having not been approved as of the date of this report, only allocations for the current criteria are currently appropriate for application.

LDEQ will work with other agencies such as local Soil Conservation Districts to implement agricultural best management practices in the watershed through the 319 programs. LDEQ will also continue to monitor the waters to determine whether standards are being attained.

In accordance with Section 106 of the federal Clean Water Act and under the authority of the Louisiana Environmental Quality Act, the LDEQ has established a comprehensive program for monitoring the quality of the state's surface waters. The LDEQ Surveillance Section collects surface water samples at various locations, utilizing appropriate sampling methods and procedures for ensuring the quality of the data collected. The objectives of the surface water monitoring program are to determine the quality of the state's surface waters, to develop a long-term data base for water quality trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program is used to develop the state's biennial 305(b) report (Water Quality Inventory) and the 303(d) list of impaired waters.

This information is also utilized in establishing priorities for the LDEQ nonpoint source program The LDEQ has implemented a watershed approach to surface water quality monitoring. Through this approach, the entire state is sampled over a five-year cycle with two targeted basins sampled each year. Long-term trend monitoring sites at various locations on the larger rivers and Lake Pontchartrain are sampled throughout the five-year cycle. Sampling is conducted on a monthly basis or more frequently if necessary to yield at least 12 samples per site each year. Sampling sites are located where they are considered to be representative of the waterbody. Under the current monitoring schedule, targeted basins follow the TMDL priorities. In this manner, the first TMDLs will have been implemented by the time the first priority basins will be monitored again in the second five-year cycle. This will allow the LDEQ to determine whether there has been any improvement in water quality following implementation of the TMDLs. As the monitoring results are evaluated at the end of each year, waterbodies may be added to or removed from the 303(d) list. The sampling schedule for the first five-year cycle is shown below.

1998 - Mermentau and Vermilion-Teche Basins
1999 - Calcasieu and Ouachita River Basins
2000 - Barataria and Terrebonne Basins
2001 - Lake Pontchartrain Basin and Pearl River Basin
2002 - Red and Sabine River Basins

Atchafalaya and Mississippi Rivers will be sampled continuously. Mermentau and Vermilion-Teche Basins will be sampled again in 2003.

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This TMDL was performed by a multidisciplinary team of people at FTN Associates with assistance from LDEQ personnel, subcontractors, and other government agencies. The LDEQ project manager was Dick Duerr and the FTN project manager was Dennis Ford. The guidance and assistance from Mr. Duerr throughout this project was extremely valuable. Dr. Ford provided general oversight and supervision for all phases of the project.

The reconnaissance survey was performed by FTN personnel (Philip Massirer and Mark Uguccioni) and the LDEQ project manager (Dick Duerr) with assistance from subcontractors.

The intensive survey was performed by several FTN personnel (Philip Massirer, Gerry Conley, and Cassandra Prewett) with assistance from subcontractors. The subcontractor personnel included Troy Dupre, Ricky Billiot, and Gary Guidry from T. Baker Smith & Sons in Houma, LA; and Kevin Hennigan from Consumer Environmental Services in Baton Rouge, LA.

Laboratory analyses of water samples were performed by Specialized Assays, Inc. in Nashville, TN.

Meteorological data were provided by the Louisiana Office of State Climatology in Baton Rouge, LA. Pumping rates for Cleco's withdrawal from Bayou Cocodrie during the intensive survey were provided by personnel from the Cleco facility in St. Landry. Local information about Bayou Cocodrie was provided by John Joubert, who lives along Bayou Cocodrie on the south edge of St. Landry.

Data analyses and preparation of the survey report were performed by several FTN personnel including Pat Downey, Philip Massirer, Gerry Conley, Cassandra Prewett, Christina Laurin, Mark Uguccioni, Sharon Baker, and others.

The water quality modeling and TMDL calculations and preparation of this report were done by Cassandra Prewett with guidance from Philip Massirer.

1.0 INTRODUCTION

The 1996 and 1998 303(d) lists and the Modified Court Ordered 303(d) list cited parts of the Bayou Cocodrie system (WQ Subsegments 060101, 060102, 060201, 060202, and 060203) as being impaired due to organic enrichment/low DO and required the development of Total Maximum Daily Loads (TMDLs) for dissolved oxygen (DO). Subsegments 060102, 060201, 060202, and 060203 are listed in the court ordered document and Subsegments 060102, 060201, and 060203 are listed in the 1998 document. The three subsegments on the 1998 list for organic enrichment/low DO (060102, 060201, and 060203) were ranked priority one. A calibrated water quality model for the system was developed and projections were modeled to quantify the point source and non-point source waste load reductions which would be necessary in order for the Bayou Cocodrie system to comply with either existing or proposed water quality standards and criteria. This report presents the results of that analysis.

2.0 STUDY AREA DESCRIPTION

2.1 General Information

The Bayou Cocodrie system is located in southern Louisiana in the Vermilion-Teche basin between Alexandria and Lafayette (Figure A.1). The components of the Bayou Cocodrie system that are the focus of this survey are:

- Spring Creek
- Cocodrie Lake
- Bayou Cocodrie from Cocodrie Lake to the confluence with the Diversion Canal
- Bayou Boeuf-Cocodrie Diversion Canal from near Lecompte to Bayou Cocodrie
- Lake Chicot
- Bayou Chicot from Lake Chicot spillway to the confluence with Bayou Cocodrie
- Bayou Cocodrie from the confluence with the Diversion Canal to the mouth

Each of these components is shown on Figure A.2. The watershed for the Bayou Cocodrie system includes rolling, hilly areas that are forested as well as flat, lowland areas that include cropland, forests, and swamps. Land use is summarized in Table 2.1.

Cocodrie Lake is a shallow lake that is mostly covered with timber. During the reconnaissance, depths of 4-6 ft were observed. However, during the intensive survey, the depth was only about 3 ft. Inflows to Cocodrie Lake include the upper part of Bayou Cocodrie, Spring Creek, Little Spring Creek, and Hurricane Creek. The total drainage area of Cocodrie Lake is approximately 227 mi^2 (USGS, 1971). The outlet of Cocodrie Lake consists of an uncontrolled overflow spillway across the channel of Bayou Cocodrie near Highway 167. The lake can be drawn down below the spillway level via a bypass valve and a control.

Downstream of Cocodrie Lake, Bayou Cocodrie flows generally southeast. Inflows to Bayou Cocodrie downstream of Cocodrie Lake include Bayou Chicot and the Bayou Boeuf-Cocodrie

Diversion Canal. Bayou Cocodrie from Highway 167 to the confluence with the Bayou Boeuf-Cocodrie Diversion Canal has been designated as an outstanding natural resource waterbody by LDEQ.

Table 2.1. Land uses in WQ Segments 0601 (Upstream of Cocodrie Dam) and 0602 (Downstream of Cocodrie Dam). Source: LDEQ, 1993.

Land Use Type	% of Total Area	
	Segment 0601	Segment 0602
Urban	1.4	4.5
Extractive	0.0	0.3
Agricultural	9.4	64.1
Forest Land	80.3	23.2
Water	0.2	0.5
Wetland	6.2	6.9
Barren Land	2.5	0.4
Other	0.0	0.0
TOTAL	100	100

The Bayou Boeuf-Cocodrie Diversion Canal is a man made channel that allows water to be diverted away from Bayou Boeuf near Lecompte. The Diversion Canal flows southeast from near Lecompte to the point where it merges with Bayou Cocodrie southeast of St. Landry. Flow into the Diversion Canal is regulated by a weir across the Diversion Canal located several hundred feet downstream of the main channel of Bayou Boeuf. When the water level in Bayou Boeuf rises above the top of the weir (e.g., during floods), large amounts of water can flow into the Diversion Canal. During low flow periods, the only water that flows from Bayou Boeuf into the Diversion Canal is through an orifice in the weir. The orifice is approximately 1-2 ft in diameter and is positioned several feet below the crest of the weir. During the reconnaissance on July 15-16, 1999, the water level in Bayou Boeuf was approximately 1.5 ft below the crest of the weir. During the intensive survey, the water level in Bayou Boeuf was similar.

Lake Chicot is an impoundment that was created by building a dam across Bayou Chicot. The dam has an uncontrolled overflow spillway (i.e., functions as a weir). During the reconnaissance on July 15-16, 1999, the level of the lake was only a few inches above the crest of the spillway. During the intensive survey, the water level was about 6 inches below the crest of the spillway and there was no water flowing out of the lake. The lake is approximately 16-17 ft deep near the dam. There are many trees in shallower parts of the lake, particularly near the upstream (south) end. The drainage area of Lake Chicot is approximately 36 mi^2 (USGS, 1971).

Downstream of Lake Chicot, Bayou Chicot flows approximately 1.6 miles before entering Bayou Cocodrie. There are no significant inflows to this reach of Bayou Chicot.

Downstream of Bayou Chicot and the Diversion Canal, Bayou Cocodrie continues flowing southeast until it ends at its confluence with Bayou Boeuf. Part of this reach of Bayou Cocodrie consists of a straight, man made channel that cuts through the original meandering channel. In this area, each "oxbow" created by the new channel is blocked at one end so that all of the flow is forced through the man made channel. The total drainage area for Bayou Cocodrie at its mouth (the confluence with Bayou Boeuf) is approximately 466 mi^2 (USGS, 1971). The confluence of Bayou Cocodrie and Bayou Boeuf forms the upstream end of Bayou Courtableau.

2.2 Water Quality Standards

The water quality criteria and designated uses for subsegments in the Bayou Cocodrie system are shown in Table 2.2. Note that although the current year-round criteria for dissolved oxygen is 5.0 mg/l, LDEQ has proposed a summer criteria of 3.0 mg/l for Cocodrie Lake and Bayou Cocodrie and a summer criteria of 4.0 mg/l for Chicot Lake.

Table 2.2. Water Quality Numerical Criteria and Designated Uses. (LDEQ, 1999a).

Subsegment	**060101**	**060102**	**060201**	**060202**	**060203**
Stream Description	**Spring Creek – Headwaters to Cocodrie Lake**	**Cocodrie Lake**	**Bayou Cocodrie – from US Hwy. 167 to Bayou Boeuf-Cocodrie Diversion Canal**	**Bayou Cocodrie- from Cocodrie Diversion Canal to intersection with Bayou Boeuf**	**Chicot Lake**
Designated Uses	ABCG	ABC	ABCG	ABC	ABC
Criteria:					
Chloride, mg/L	10	10	45	45	90
Sulfate, mg/L	5	5	34	35	30
DO, mg/L (existing)	5	5	5	5	5
DO, mg/L (proposed)	no change	3: March-Nov 5: Dec-Feb	3: March – Nov 5: Dec-Feb	3: March – Nov 5: Dec-Feb	4: June-Oct 5: Nov-May
pH, su	6.0 - 8.5	6.0 - 8.5	6.0 - 8.5	6.0 - 8.5	6.0 - 8.5
Temp, ºC	30	32	32	32	32
TDS, mg/L	100	100	100	100	260

Uses: A – primary contact recreation; B – secondary contact recreation; C – propagation of fish and wildlife; D – drinking water supply; E – oyster propagation; F – agriculture; G – outstanding natural resource water; L – limited aquatic life and wildlife use.

2.3 Wastewater Discharges

The discharger inventory for the Bayou Cocodrie system was reviewed. Five point source discharges were included in this study (Table 2.3). Other point source dischargers were identified within the Bayou Cocodrie watershed but were considered too far away and/or too small to directly impact any of the waterbodies that are part of the system.

Table 2.3. Point source discharges included in the model of the Bayou Cocodrie system.

Name	Sampling station ID	Permit number	Receiving water	Design flow (MGD)	Permit limits (mg/L)
Village of Forest Hill	ForH	LAG570142	Hurricane Creek, then to Cocodrie Lake	0.074	10 BOD_5
City of Glenmora	Glen	LA0054925	Little Spring Creek, then to Cocodrie Lake	0.228	10 BOD_5
Cleco Coughlin Power Station	Cleco	LA0002879	Bayou Cocodrie	114.8 (sum) 116.6 (win)	Temp & pH only
Chicot State Park WWTP	LCSP	LAG540413	Lake Chicot	0.012	30 BOD_5
Plaquemines Alligator Farm	Allig	LA0109011	Choctaw Bayou, then to Lake Chicot	0.08	30 BOD_5 Report NH_3

2.4 Water Quality Conditions/Assessment

Table 2.4a lists the designated uses for the LDEQ waterbody subsegments within the study area. All of the waterbodies in Table 2.4a are on Louisiana's 1998 303(d) list except for Bayou Cocodrie between the confluence with the Diversion Canal and the confluence with Bayou Boeuf (LDEQ, 1998). The suspected causes of impairment for these subsegments are listed in Table 2.4b. Other waterbodies that were included in this study (e.g., Hurricane Creek, Little Spring Creek, the Diversion Canal) are not listed separately in the water quality standards.

Table 2.4a. Designated uses for waterbodies within the Bayou Cocodrie system.

Waterbody description and LDEQ subsegment number	Designated Uses	Designated uses not fully supported (based on 1998 303(d) list)
Spring Creek from headwaters to Cocodrie Lake (060101)	Primary contact recreation, Secondary contact recreation, Fish and wildlife propagation, Outstanding natural resources	Primary contact recreation, Fish and wildlife propagation, Outstanding natural resources (partial support)
Cocodrie Lake (060102)	Primary contact recreation, Secondary contact recreation, Fish and wildlife propagation	Fish and wildlife propagation
Bayou Cocodrie from U.S. Hwy 167 to confluence with the Bayou Boeuf-Cocodrie Diversion Canal (060201)	Primary contact recreation, Secondary contact recreation, Fish and wildlife propagation, Outstanding natural resources	Fish and wildlife propagation, Outstanding natural resources (partial support)
Bayou Cocodrie from confluence with Diversion Canal to confluence with Bayou Boeuf (060202)	Primary contact recreation, Secondary contact recreation, Fish and wildlife propagation	All uses supported (not on 303(d) list)
Chicot Lake, including Bayou Chicot (060203)	Primary contact recreation, Secondary contact recreation, Fish and wildlife propagation	Fish and wildlife propagation

Table 2.4b. Suspected Causes of Impairment.

Waterbody description and LDEQ subsegment number	Based on the 1998 303(d) List	Based on the Modified Court Ordered 303(d) List
Spring Creek from headwaters to Cocodrie Lake (060101)	Siltation Pathogen indicators Turbidity Metals	Suspended solids
Cocodrie Lake (060102)	Organic enrichment/low DO Metals	Organic enrichment/low DO Ammonia Siltation Noxious aquatic plants
Bayou Cocodrie from U.S. Hwy 167 to confluence with the Bayou Boeuf-Cocodrie Diversion Canal (060201)	Organic enrichment/low DO Turbidity Metals	Organic enrichment/low DO Copper Suspended solids
Bayou Cocodrie from confluence with Diversion Canal to confluence with Bayou Boeuf (060202)	None	Organic enrichment/low DO Suspended solids Turbidity Nutrients Siltation
Chicot Lake, including Bayou Chicot (060203)	Organic enrichment/low DO Metals	Organic enrichment/low DO Mercury Nutrients Suspended solids Turbidity Noxious aquatic plants

2.5 Prior Studies

Previous water quality data collected for the Bayou Cocodrie system include the following:

1. Monthly data collected by LDEQ for "Spring Creek near Glenmora" (station 99) for 1978 to present. This station is located at the Highway 165 bridge (approximately same location as Sprg-1 on Figure A.2).

2. Bi-monthly data collected by LDEQ for "Bayou Cocodrie northeast of Oakdale" (station 311) for 1991 to present. This station is located at the Highway 167 bridge (same location as BCoc-2 on Figure A.2).

3. Monthly data collected by LDEQ for "Bayou Cocodrie at St. Landry" (station 103) for 1978 to 1990, and bi-monthly from 1992 to present. This station is located at the Highway 106 bridge (same location as BCoc-5 on Figure A.2).

4. Monthly data collected by LDEQ for "Lake Chicot north of Ville Platte" (station 312) for 1991 to present. This station is located at the Lake Chicot spillway (approximately same location as LChi-3 on Figure A.2).

5. Bi-weekly data collected by LDEQ for “Cocodrie Lake” (station 663) and “Bayou Cocodrie Diversion Canal” (station 664) for June - December 1998. Station 664 is located at the Highway 29 bridge (same location as BCoc-6 on Figure A.2).

6. Data collected by U.S. EPA during 1974-75 for the following stations: Spring Creek, Little Spring Creek, Hurricane Creek, Bayou Cocodrie at Highway 167, and Bayou Cocodrie upstream of Cocodrie Lake.

7. Data collected by USGS for the following stations: Spring Creek near Glenmora (1966-88), Bayou Cocodrie at Highway 167 (1944-79), Lake Chicot north of Ville Platte (1975-76), and Cocodrie Lake (1970, 1975-76).

8. Data collected by U.S. Forest Service for Spring Creek near Glenmora (1985-90).

3.0 DOCUMENTATION OF CALIBRATION MODEL

3.1 Model Description and Input Data Documentation

3.1.1 Program Description

“Simulation models are used extensively in water quality planning and pollution control. Models are applied to answer a variety of questions, support watershed planning and analysis and develop total maximum daily loads (TMDLs) . . . Receiving water models simulate the movement and transformation of pollutants through lakes, streams, rivers, estuaries, or nearshore ocean areas Receiving water models are used to examine the interactions between loadings and response, evaluate loading capacities (LCs), and test various loading scenarios . . . A fundamental concept for the analysis of receiving waterbody response to point and nonpoint source inputs is the principle of mass balance (or continuity). Receiving water models typically develop a mass balance for one or more constituents, taking into account three factors: transport through the system, reactions within the system, and inputs into the system.” (EPA841-B-97-006, pp. 1-30)

The model used for this TMDL was QUAL-TX, “a steady-state one-dimensional water quality model that has been developed by the Water Quality Standards and Evaluation Section of the Texas Water Commission. It is a modified version of QUAL-II. The original QUAL-II model was developed by Water Resources Engineers (now Camp Dresser & McKee) for the United States Environmental Protection Agency. Since that time, many modifications have been made to QUAL-II by many people. QUAL-TX is a user oriented model incorporating many of those modifications and is intended to provide the basis for evaluating waste load allocations in the State of Texas.” (QUAL-TX User’s Manual, rev. 1990). QUAL-TX was selected since it offers the ability to model branched systems and it has been used successfully in Louisiana in the past.

“The development of a TMDL for dissolved oxygen generally occurs in 3 stages. Stage 1 encompasses the data collection activities. These activities may include gathering such information as stream cross-sections, stream flow, stream water chemistry, stream temperature and dissolved oxygen at various locations on the stream, location of the stream centerline and the boundaries of the watershed which drains into the stream, and other physical and chemical factors which are associated with the stream. Additional data gathering activities include gathering all available information on each facility which discharges pollutants in to the stream, gathering all available stream water quality chemistry and flow data from other agencies and groups, gathering population statistics for the watershed to assist in developing projections of future loadings to the water body, land use and crop rotation data where available, and any other information which may have some bearing on the quality of the waters within the watershed. During Stage 1, any data available from reference or least impacted streams which can be used to gauge the relative health of the watershed is also collected."

"Stage 2 involves organizing all of this data into one or more useable forms from which the input data required by the model can be obtained or derived. Water quality samples, field measurements, and historical data must be analyzed and statistically evaluated in order to determine a set of conditions which have actually been measured in the watershed. The findings are then input to the model. Best professional judgement is used to determine initial estimates for parameters which were not or could not be measured in the field. These estimated variables are adjusted in sequential runs of the model until the model reproduces the field conditions which were measured. In other words, the model produces a value of the dissolved oxygen, temperature, or other parameter which matches the measured value within an acceptable margin of error at the locations along the stream where the measurements were actually made. When this happens, the model is said to be calibrated to the actual stream conditions. At this point, the model should confirm that there is an impairment and give some indications of the causes of the impairment. If a second set of measurements is available for slightly different conditions, the calibrated model is run with these conditions to see if the calibration holds for both sets of data. When this happens, the model is said to be verified.

"Stage 3 covers the projection modeling which results in the TMDL. The critical conditions of flow and temperature are determined for the waterbody and the maximum pollutant discharge conditions from the point sources are determined. These conditions are then substituted into the model along with any related condition changes which are required to perform worst case scenario predictions. At this point, the loadings from the point and nonpoint sources (increased by an acceptable margin of safety) are run at various levels and distributions until the model output shows that dissolved oxygen criteria are achieved. It is critical that a balanced distribution of the point and nonpoint source loads be made in order to predict any success in future achievement of water quality standards. At the end of Stage 3, a TMDL is produced which shows the point source permit limits and the amount of reduction in man-made nonpoint source pollution which must be achieved to attain water quality standards. The man-made portion of the NPS pollution is estimated from the difference between the calibration loads and the loads observed on reference or least impacted streams." (LDEQ, 1999b)

The model was hydrologically calibrated to the 1999 survey measurements of flow and conductivity. Water quality parameters and coefficients were then established based on available data and best professional judgement. The calibration model output was then compared to the 1999 survey measurements of water quality and the calibration was determined to be successful.

3.1.2 Model Configuration

A vector diagram of the modeled area is presented in Appendix B.1. The vector diagram shows the locations of survey stations, the reach/element design, the locations of modeled tributaries and WWTPs, and the locations of tributaries contributing flow but not modeled (e.g., Spring Creek).

The constituents simulated in the model were CBODu, organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, and DO. Due to the low concentrations of phosphorus and chlorophyll a measured during the 1999 intensive survey, these parameters were not simulated. Also, supersaturated DO readings were not observed during the field survey, which indicates low levels of algae.

3.1.3 Hydrology and Stream Geometry and Sources

The USGS has published historical daily streamflow data for Spring Creek near Glenmora (at Highway 165) and for Bayou Cocodrie near Clearwater (at Highway 167, just downstream of Cocodrie Lake). Flow data were not available from the USGS for the survey period for either gage. LDEQ has monthly water quality sampling stations for Spring Creek near Glenmora, for Bayou Cocodrie at Highway 167, for Bayou Cocodrie at St. Landry, and for Lake Chicot near the dam. In July, 1998, the LDEQ began a new ambient monitoring strategy which focuses on each basin intensely for a limited period of time over a five year cycle. During June - December 1998, the four sites listed above plus two additional sites in the Bayou Cocodrie watershed were monitored twice a month. The additional sites were Cocodrie Lake and Bayou Cocodrie at Highway 29 (south of St. Landry). LDEQ continues to perform monthly sampling at the four sites listed above as part of a statewide trend program. Data from these stations was used to determine critical temperatures for each season and to evaluate critical flows.

Data collected during an intensive survey conducted from September 9-11, 1999, was used to establish the input for the model calibration and is summarized in Appendix C. The reaches and elements for the Bayou Cocodrie system were designed to provide sufficient detail to show spatial variations of water quality but without exceeding the model limitations for the maximum numbers of reaches and elements. The resulting design incorporated 23 reaches, 3 headwaters, 5 point source discharges, 4 unmodeled tributaries, 1 withdrawal, and 178 elements.

The flow in each reach, headwater, and unmodeled tributary was determined based on the survey discharge measurements, the drainage area associated with each flow, and a determination of appropriate incremental nonpoint source flowrate in terms of cfs/reach. Treatment plant flows were determined based on survey measurements and available data from permits and DMRs. Flow balances for the Cocodrie Dam area and for the St. Landry area are presented in Appendix D.

Field data, topographic maps, and visual observations during the surveys were used to develop depths and widths for the Bayou Cocodrie system. Values of average depth were obtained from cross section measurements from the intensive survey. Figures E.1 and E.2 (in Appendix E) show the longitudinal variation of depths in Bayou Cocodrie. Table E.1 compares measured depths throughout the system with values used for the model calibration.

Stream widths were estimated using cross section measurements from the intensive survey. Figures E.3 and E.4 show the longitudinal variation of widths in Bayou Cocodrie. For the lakes (Cocodrie Lake and Lake Chicot), average widths were estimated by digitizing surface areas from USGS 7.5 minute topographic maps and dividing the surface areas by the reach lengths. Table E.2 compares measured widths throughout the system with values used for the model calibration.

The hydraulics for each reach were specified in QUAL-TX model using the power functions (velocity = a * Q^b and depth = c * Q^d + e). For the stream reaches (as opposed to the lakes), the depths and widths would be expected to exhibit some change as the flow rate changes. There was insufficient data from the field survey to develop relationships between depth vs. flow and velocity vs. flow. Literature values were used for the exponents (b and d) in these relationships. The exponents for these reaches were values developed by Leopold that were averages for 158 USGS gaging stations as cited in the WASP Users' Manual (EPA, 1993). The coefficients were then back-calculated using the observed values of flow, velocity, and depth. The model input values for these reaches were specified as follows:

- velocity during survey = (flow during survey) ÷ (depth * width)
- velocity coefficient (a) = (velocity during survey) ÷ [(flow during survey)$^{0.43}$]
- velocity exponent (b) = 0.43
- depth coefficient (c) = (depth during survey) ÷ [(flow during survey)$^{0.45}$]
- depth exponent (d) = 0.45
- depth constant (e) = 0.0

For the lakes (Cocodrie Lake and Lake Chicot), the water levels can be assumed to be independent of flow rate. Therefore, the lakes were modeled with constant depths and widths. This was specified in the model by setting the coefficients and exponents as follows:

- velocity coefficient (a) = 1.0 / cross sectional area = 1.0 / (width * depth)
- velocity exponent (b) = 1.0
- depth coefficient (c) = depth
- depth exponent (d) = 0.0
- depth constant (e) = 0.0

The measured velocities from the time of travel studies during the intensive survey were compared with velocities that the model calculated using the power functions above. This comparison was made for both of the time of travel studies (one between BCoc-3 and BCoc-4 and the other one near BCoc-6). The results of these comparisons are shown in Table E.3.

Because the Bayou Cocodrie system is not tidal in nature, all of the dispersive hydraulic coefficients were set to zero. The field data and the model results indicated that longitudinal dispersion was not having a significant impact on water quality.

3.1.4 Headwater and Waste Water Loads

Water quality for upstream inflows and for treatment plant wasteloads were derived primarily from field data with use of DMRs as supplementary information.

3.1.5 Water Quality Input Data and Their Sources

Water quality data collected during the September 9-11, 1999 survey for the Bayou Cocodrie system were entered in a spreadsheet for ease of analysis. The Louisiana GSBOD program was applied to the BOD data in the spreadsheet and values of ultimate CBOD and CBOD decay rate were computed for each sample. This survey data was the primary source for the model input data for CBOD decay rates, incremental inflow quality, headwater data, and wasteload data.

3.1.5.1 Water Quality Program Constants, Data Type 3

The value for the minimum surface transfer rate for reaeration (K_L) was changed from the model default (0.6 m/day) to 0.7 m/day to be consistent with the minimum reaeration specified in the Louisiana TMDL Technical Procedures Manual (LTP).

3.1.5.2 Temperature Correction of Kinetics, Data Type 4

The temperature correction factors used in the model were consistent with the LTP. These correction factors were:

- Correction for BOD decay: 1.047 (value in LTP is same as model default)
- Correction for SOD: 1.065 (specified in Data Group 4)
- Correction for reaeration: 1.024 (specified in Data Group 4)
- Correction for ammonia N decay: 1.070 (specified in Data Group 4)
- Correction for organic N decay: 1.047 (not specified in LTP; model default used)

3.1.5.3 Initial Conditions, Data Type 11

The initial conditions are used to specify starting values for the model iterations as well as specify the temperature for each reach (because temperature was not being simulated). The values required for this model are temperature, DO, organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, and ultimate CBOD (CBODu) by reach. Phosphorus and chlorophyll a concentrations measured during the 1999 intensive survey were low, indicating low levels of algae. Therefore, phosphorus and chlorophyll a were not simulated. The input values for temperature were based on values measured during the field study. The input data and sources are shown in Appendix F. Included in Appendix F is a table comparing temperatures used in the model with measured temperatures throughout the Bayou Cocodrie system.

3.1.5.4 Reaeration, SOD, and CBOD Decay Rates, Data Type 12

The values used in the model input for reaeration equations, SOD, and CBOD decay are shown in Appendix F. The Texas Equation option was specified for reaeration in the model because it has been used successfully in previous Louisiana TMDLs. For the lakes, the slow velocities caused the Texas Equation to yield a reaeration rate lower than the QUAL-TX minimum reaeration rate (K_L divided by depth). For those cases, the model used K_L divided by depth for the effective reaeration rate. The SOD rates were developed through iteration in the calibration. SOD values were adjusted so that predicted DO concentrations were similar to measured DO concentrations.

CBOD decay was estimated based on "bottle rates" from the CBOD time series data. The time series data were entered into the GSBOD spreadsheet program used by LDEQ. This spreadsheet program fits a first order decay curve to the CBOD time series data and calculates the associated decay rate. The results of the GSBOD program are included in Table C.1 (in Appendix C). The CBOD decay rates for all reaches were set to 0.15/day, which was the median of the decay rates calculated with the GSBOD program for all of the sampling stations. The CBOD settling rates were set to zero to be conservative.

3.1.5.5 Kinetic Rates for Nitrogen, Data Type 13

Mineralization (organic nitrogen decay) was set to a constant value of 0.05/day for all reaches. This value was based on the EPA document "Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling" (EPA 1985). The organic nitrogen settling rates were set to zero to be conservative. Nitrification rates were set to 0.1/day for all reaches. For uncalibrated models, the LTP recommends using nitrification rates higher than 0.1/day for streams with depths less than 2 ft. However, because calibration data were available and the model calibrated well using the value of 0.1/day, the nitrification rates were not varied with depth.

Nonpoint source loads of ammonia nitrogen were specified in data type 13 (benthic release of ammonia nitrogen); these inputs are discussed below with the other nonpoint source load inputs (data type 19).

3.1.5.6 Incremental Conditions, Data Types 16, 17, and 18

The incremental conditions were used in the calibration to represent nonpoint source loads associated with flows. The incremental flow was added to Bayou Cocodrie in order for the flow to balance at St. Landry. A flow balance was developed based on the measured outflow from Cocodrie Lake, the measured flow being discharged by Cleco from Mountain Bayou Lake, Cleco's estimated withdrawal rate (obtained from Cleco personnel), and the measured flow in

Bayou Cocodrie downstream of Cleco's discharge and withdrawal. This flow balance indicated that an additional 38.5 cfs of flow was needed in Bayou Cocodrie between Cocodrie Lake and the confluence with Bayou Chicot. This flow was added as incremental inflow for reaches 6-11 (river mile 40 to 18.4). This flow balance was confirmed through a conductivity balance on Bayou Cocodrie at the point where Cleco's discharge enters Bayou Cocodrie. (see Appendix D). The water quality for the incremental inflows was set to the average of the observed concentrations for BCoc-2, BCoc-3, and BCoc-4 because these three stations were assumed to be the most representative of inflow for those reaches.

3.1.5.7 Nonpoint Sources, Data Type 19

Nonpoint source loads which are not associated with a flow are input into this part of the model. These loads were specified only for the lakes. Each load was calculated assuming that nonpoint source loads were responsible for maintaining certain minimum "background" concentrations of BOD, organic nitrogen, and ammonia nitrogen. With this assumption, nonpoint loads can be calculated as the concentration in the water body (mg/L) times the temperature corrected decay rate (1/day) times the volume of water in that element (L) times a conversion factor (1.0E-6 kg/mg). This load represents the mass of each constituent that is needed to replace what is being lost to decay (i.e., transformation). Without these loads, the model would predict nearly complete disappearance of these constituents due to decay over the long travel times that occur in each lake. Observed water quality data in each lake indicate that these constituents do not completely disappear and that nonpoint loads are needed to simulate these waterbodies. In some cases, the calculated loads were adjusted to improve the calibration (particularly where the DO was low enough to inhibit the decay rates, which required an estimation of the inhibition factor in the load calculations). The load calculations and input data are presented in Appendix F.

3.1.5.8 Headwaters, Data Types 20, 21, and 22

The flow rates and water quality concentrations for the headwaters (Little Spring Creek, Hurricane Creek, and Choctaw Bayou) were based on measured values from the intensive survey. The input data and sources are presented in Appendix F.

3.1.5.9 Wasteloads, Data Types 24, 25, and 26

The wasteloads entered in the model were of two different types: point source discharges and unmodeled tributaries. There are no known point source dischargers to the unmodeled tributaries except for the Town of Cheneyville WWTP discharge into the Diversion Canal. Several of the unmodeled tributaries were sampled during the survey and the results of these samples were the basis for the input data. The only unmodeled tributary that was not sampled was Bayou Chicot (which was completely dry during the survey). Measured data for Choctaw Bayou were used for Bayou Chicot. The wasteloads from the treatment plants were determined from field data and DMRs. The input data and sources are presented in Appendix F.

3.1.5.10 Boundary Conditions, Data Type 27

Because longitudinal dispersion was not specified for this model, lower boundary conditions were not specified.

3.2 Model Discussion and Results

The calibration model output is presented in Appendix G. Plots of the predicted and observed water quality versus river mile are presented in Appendix H.

4.0 WATER QUALITY PROJECTIONS

Since the calibrated model indicated that the DO criterion was not being met in parts of the Bayou Cocodrie systems, three summer loading scenarios were performed in addition to the traditional summer and winter projections. These additional scenarios were:

a. No Load Scenario - No point source loads and no nonpoint source loads above reference stream background
b. No Discharge Scenario - No point source loads with the calibrated nonpoint source loads
c. No NPS Scenario - Current permitted dischargers with no NPS loads above reference stream background

4.1 Critical Conditions

4.1.1 Seasonality and Margin of Safety

“The Clean Water Act requires the consideration of seasonal variation of conditions affecting the constituent of concern, and the inclusion of a margin of safety (MOS) in the development of a TMDL. For the Bayou Cocodrie TMDL, an analysis of LDEQ long-term ambient data was used to determine critical seasonal conditions. Explicit margins of safety of 20% for point and 10% for non-point loading were used in developing the projections models."

Critical conditions for dissolved oxygen were determined for the Vermilion-Teche Basin using long term water quality data from several stations on the LDEQ Ambient Monitoring Network and the Louisiana Office of State Climatology water budget. Graphical and regression techniques were used to evaluate the temperature and dissolved oxygen data from the Ambient Monitoring Network and the run-off determined from the water budget. Since nonpoint loading is conveyed by run-off, this seemed a reasonable correlation to use. Temperature is strongly inversely proportional to dissolved oxygen and moderately inversely proportional to run-off. Dissolved oxygen and run-off are also moderately directly proportional. The analysis concluded that the critical conditions for stream dissolved oxygen concentrations were those of negligible nonpoint run-off and low stream flow combined with high stream temperature.

When the rainfall run-off (and non-point loading) and stream flow are high, turbulence is higher due to the higher flow and the temperature is lowered by the run-off. In addition, run-off coefficients are higher in cooler weather due to reduced evaporation and evapotranspiration, so that the high flow periods of the year tend to be the cooler periods. DO saturation values are, of course, much higher when water temperatures are cooler, but BOD decay rates are much lower.

For these reasons, periods of high loading are periods of higher reaeration and dissolved oxygen but not necessarily periods of high BOD decay.

This phenomenon is interpreted in TMDL modeling by assuming that the annual nonpoint loading, rather than loading for any particular day, is responsible for the accumulated benthic blanket of the stream, which is, in turn, expressed as SOD and/or resuspended BOD in the model. This accumulated loading has its greatest impact on the stream during periods of higher temperature and lower flow. The manmade portion of the NPS loading is the difference between the calibration load and the reference stream load where the calibration load is higher.

According to the LTP, critical summer conditions were simulated in the Bayou Cocodrie dissolved oxygen TMDL projection modeling by using the annual 7Q10 flow or 0.1 cfs, whichever is higher, for all headwaters, and 90th percentile temperature for the summer season. Incremental flow was assumed to be zero; model loading was from point sources, perennial tributaries, sediment oxygen demand, and resuspension of sediments. Critical winter conditions were simulated by using the lowest of the monthly 7Q10 flow published for the winter months or 1 cfs, whichever was higher, for all headwaters, and 90th percentile temperature for the season. Again, incremental flow was assumed to be zero; model loading was from point sources, perennial tributaries, sediment oxygen demand, and resuspension of sediments. In addition, all point sources were assumed to be discharging at maximum capacity.

In reality, the highest temperatures occur in July-August, the lowest stream flows occur in October-November, and the maximum point source discharge occurs following a significant rainfall, i.e., high-flow conditions. The combination of these conditions plus the impact of other conservative assumptions regarding rates and loadings yields an implied margin of safety that is not quantified. Over and above this implied margin of safety, LDEQ typically reserves an explicit MOS of 20% for point and up to 10% for nonpoint loads to account for future growth and model uncertainty.

4.1.2 Hydrology and Stream Geometry and Sources

In accordance with the LTP, flows for the projection runs were based on 7Q10 conditions. The only tributaries considered to have a non-zero annual 7Q10 were Spring Creek and the Diversion Canal. Other tributaries (Little Spring Creek, Hurricane Creek, Choctaw Bayou, and Bayou Chicot) were assumed to have no flow during annual 7Q10 conditions based on field observations and size of drainage area. An additional flow was added to Bayou Cocodrie at Cocodrie Dam because the outflow from Cocodrie Lake exceeds the inflow to the lake for long periods of time during low flow conditions. This phenomenon can occur due to operation of a valve in Cocodrie Dam that is opened to allow water to continue to flow out of the lake even after the level of the lake has dropped below the top of the spillway. The amount of flow added to Bayou Cocodrie in the model was calculated as the published 7Q10 for Bayou Cocodrie near Clearwater (just downstream of Cocodrie Dam) minus the published 7Q10 for Spring Creek. Incremental inflow downstream of Cocodrie Dam was set to zero based on an annual 7Q10 flow balance for Bayou Cocodrie, Bayou Beouf, and Bayou Courtableau.

The projection runs used the same kinetic coefficients as in the calibration run. The only model inputs that were changed from the calibration to the projection runs were the temperature, inflow rates, inflow water quality, and NPS load.

Each of the treatment plant flows were set to 125% of their design flow in order to explicitly incorporate a 20% margin of safety for the point source wasteload allocations.

4.1.3 Water Quality Input Data and Their Sources.

4.1.3.1 Initial Conditions, Data Type 11

The widths and depths were assumed to be the same for the projection scenarios as for the calibration scenario. This assumption was made because the stream flow rates were similar between the projection scenarios and the calibration scenario.

The primary input that was specified in the initial conditions was the water temperature, which was set to the 90th percentile temperature for each season. Critical temperatures for each season were determined from the temperature data collected by LDEQ as part of its historical and current ambient monitoring strategy. Calculations for the 90th percentile temperatures are shown in Appendix J. The 90th percentile temperature for each season was computed using data for Bayou Cocodrie near Clearwater (at Highway 167) (reaches 1-9), Bayou Cocodrie at St. Landry (reaches 10,11, and 19-23), and Lake Chicot near the dam (reaches 12-18). Initial condition DO was set to the criteria except in reaches with headwaters. The DO concentrations in reaches with headwaters was set to 90% of the saturation value at the seasonal temperature.

For each of the model inputs that was changed for calibration to the projections, the input values and data sources are included in Appendix I. The incremental conditions were used in the calibration to represent nonpoint source loads associated with flows. For the projection and scenario runs, the incremental flows were set to zero to emulate the critical conditions for dissolved oxygen.

4.1.3.2 Nonpoint Sources, Data Type 19

For the projection runs, the nonpoint source (NPS) loads from the calibration run were divided between natural NPS loads and manmade NPS loads. This was done by estimating the natural NPS loads and then designating the remainder of the NPS loads from the calibration run as manmade NPS loads. When dividing NPS loads between natural and manmade, the total NPS loading is considered to be the sum of SOD, benthic ammonia nitrogen, nonpoint CBODu, and nonpoint organic nitrogen.

Initially, the natural nonpoint source loads were set to the average values from the reference stream data (Smythe, 1997). These values are shown in Table 1 in Appendix K. However, in many segments, these natural loads were greater than the loads used in the calibration (Table 2 in Appendix K). The maximum natural NPS load was estimated as approximately 1.0 g/m^2/day of oxygen demand for smaller streams and 1.5 g/m^2/day of oxygen demand for Cocodrie Lake and

Lake Chicot and 2.0 g/m^2/day for Bayou Cocodrie (Table 3 in Appendix K). Where the NPS loads used in the calibration were less than the natural NPS loads, the NPS loads from the calibration were used as natural NPS loads.
For the no load scenario and the no NPS scenario, the manmade NPS loads were eliminated completely. Therefore, for these two scenarios, each of the 4 components of the NPS loading was set to the values corresponding to the natural NPS loads. The individual components of the NPS loading are SOD (data type 12), benthic release of ammonia nitrogen (data type 13), mass loads of CBODu (data type 19), and mass loads of organic nitrogen (data type 19). The input values for each of the NPS components is shown in Appendix I.

For the no discharge scenario, the NPS loads were set to the same values as in the calibration run. For the summer and winter projections, the manmade NPS loads were reduced as necessary to meet the water quality standards for DO. The input values for each of the NPS components for the summer and winter projection runs are shown in Appendix I.

4.1.3.3 Headwaters, Data Type 20-22

Headwater temperatures were set to the 90th percentile seasonal temperature. DO concentrations were set to the 90% saturation concentration at the 90th percentile seasonal temperature in accordance with the LTP. Chlorine and conductivity are based upon measurements from the September 1999 field study at stations LitS-1, Hurr-1, and Choc-1. Other parameters (DO, CBODu, Organic Nitrogen, Ammonia,) were based on the average reference stream values. The values for these inputs for the projection run are presented in Appendix I.

4.1.3.4 Wasteloads, Data Types 24-26, and Unmodeled Tributaries

Flow rates for the point source discharges were based on current design flows. For the 3 projections that include point sources (no NPS scenario, summer projection, and winter projection), the point source flow rates were set to 125% of their current design flow in order to incorporate an explicit 20% margin of safety. For the other 2 scenarios (no load scenario and no discharge scenario), the point source flow rates were set to zero.

For the no NPS scenario, concentrations for the point source discharges were based on existing permit limits and guidance in the LTP. The temperatures for point sources were set to the 90th percentile seasonal temperature (same as the values specified in the initial conditions). Based on guidance from LDEQ, the DO concentrations for the point sources were set to 5.0 mg/L for Forest Hill WWTP and Glenmora WWTP. Chicot State Park and Plaquemines Alligator Farm DO concentrations were set to 2.0 mg/L. CBODu concentrations for the point sources were set to their existing $CBOD_5$ permit limits times an assumed CBODu to $CBOD_5$ ratio of 2.3. The ammonia nitrogen concentration for Chicot State Park was set to 15 mg/L, which is typical of effluent from secondary treatment according to the LTP. The ammonia nitrogen concentration for Forest Hill and the City of Glenmora was set to 10 mg/L based on the LTP and their existing CBOD limit. Based on LDEQ experience, effluent from mechanical treatment systems typically has a organic nitrogen to ammonia nitrogen ratio of 1:2, while effluent from pond systems typically has a organic nitrogen to ammonia nitrogen ratio of 2:1. Because Chicot State Park WWTP is a package plant (i.e., a mechanical system), the organic nitrogen concentration was set to 7.5 mg/L (half of their ammonia nitrogen concentration). Because Forest Hill and the City of Glenmora have a pond system for treatment, their organic nitrogen concentration was set to 20 mg/L (twice their ammonia nitrogen concentration).

For the summer projection and winter projection, the point source input values were the same as for the no NPS scenario except that discharge concentrations of CBODu, ammonia nitrogen, and organic nitrogen were reduced as needed for predicted DO values to be at or above the water quality standard. Appendix I shows the input data used for the wasteloads for the summer and winter projections.

4.2 Model Discussion and Results

The model output for the projection runs is presented in the appendices. For the summer and winter projections, complete printouts of the model output are included. For the other three scenarios, only the input files and the predicted DO is present.

4.2.1 No Load Scenario

In this scenario, the point source discharges were eliminated and the manmade NPS loadings (SOD, benthic ammonia nitrogen, nonpoint CBODu, and nonpoint organic nitrogen) were eliminated. Therefore, the model inputs for NPS loadings were set to the values used to represent natural NPS loadings (see discussion above concerning natural and manmade NPS loadings). The no load scenario does not project that the current 5.0 mg/L DO criteria can be met. The input files and the predicted DO for the no load scenario are included in Appendix L.

4.2.2 No Discharge Scenario

In this scenario, the point source discharges were eliminated and the NPS loadings (SOD, benthic ammonia nitrogen, nonpoint CBODu, and nonpoint organic nitrogen) were set to the values used in the calibration run. For the summer simulation, the predicted DO was below the proposed water quality standard in Cocodrie Lake, Choctaw Bayou, and Lake Chicot but above the standard in other parts of the system. For the winter simulation, the predicted DO was below the standard in Lake Chicot but above the standard in other parts of the system. The input files and the predicted DO for the no discharge scenario are included in Appendix L.

4.2.3 No NPS Scenario

In this scenario, the point source discharges were set at current design flows and permit limits and the manmade NPS loadings (SOD, benthic ammonia nitrogen, nonpoint CBODu, and nonpoint organic nitrogen) were eliminated. Therefore, the model inputs for NPS loadings were set to the values used to represent natural NPS loadings (see discussion above concerning natural and manmade NPS loadings). For the summer simulation, the predicted DO values were below the proposed water quality standard near Cocodrie Lake, Little Spring Creek, Choctaw Bayou, and Lake Chicot but above the standard for other parts of the system. For the winter simulation, the DO standard was met throughout the system. The input files and the predicted DO for the no NPS scenario are included in Appendix L.

4.2.4 Summer Projection

For the summer projection, the point source discharges were initially set at current design flows and permit limits and the NPS loadings (SOD, benthic ammonia nitrogen, nonpoint CBODu, and nonpoint organic nitrogen) were set to the values used in the calibration run. Then the point source and NPS inputs to the system were reduced until the predicted DO values were all at or above the current summer DO standard of 5 mg/L. A projection run was also run in order to meet the proposed DO standard of 3.0 mg/L for Bayou Cocodrie and Cocodrie Lake and 4.0 mg/L for Chicot Lake. The model output is included in Appendix M and the predicted DO values for the summer projections versus river mile are presented in Figures 4.1 through 4.6 in Appendix N. These results indicate that the DO standard of 5 mg/L cannot be maintained during the summer critical season without a 100 percent reduction of manmade nonpoint loading in Cocodrie Lake, Bayou Cocodrie, Choctaw Bayou, and Lake Chicot, and a reduction of natural background loading of 25% in Cocodrie Lake, 43% in Bayou Cocodrie below river mile 21, 43% in Bayou Choctaw, and 57% in Lake Chicot. Reductions in natural background loading cannot, of course, be implemented. The dissolved oxygen criteria of 5.0 mg/l is not appropriate to this system. Chicot State Park WWTP and Plaquemines Alligator Farm effluent limitations were also reduced to meet the standard.

In order to maintain the proposed standard, Plaquemines Alligator Farm and manmade NPS loadings were reduced. The manmade NPS loadings in the model were reduced by 20% in Cocodrie Lake just above the dam, 50% in Bayou Cocodrie between river miles 22.3 and 26.8, 20% in Bayou Cocodrie between river miles 18.4 and 16.8, and 100% in Choctaw Bayou and Lake Chicot.

The effluent limitations for the point sources needed to meet the current and proposed criteria are shown below in Table 4.1.

Table 4.1. Effluent Limitations for Summer.

Discharger	BOD (mg/l) Proposed Criteria	BOD (mg/L) Current Criteria	NH3-N (mg/l) Proposed Criteria	NH3-N (mg/l) Current Criteria	Org-N (mg/l) Proposed Criteria	Org-N (mg/l) Current Criteria	DO (mg/l) Proposed Criteria	DO (mg/l) Current Criteria
Glenmora	10	10	10	2	20	4	5.0	6.0
Forest Hill	10	10	10	10	20	20	2.0	2.0
Plaquemines Alligator Farm	10	10	5.0	5.0	2.5	2.5	2.0	6.0
Chicot State Park	30	10	15	10	7.5	5	2.0	5.0

4.2.5 Winter Projection

For the winter projection, the point source discharges were initially set at current design flows and permit limits and the NPS loadings (SOD, benthic ammonia nitrogen, nonpoint CBODu, and nonpoint organic nitrogen) were set to the values used in the calibration run. Then both the point source and NPS inputs to the system were reduced until the predicted DO values were all at or above the winter DO standard of 5 mg/L. The predicted DO values versus river mile for the winter projection is presented in Figures 4.7 through 4.9 in Appendix N and the model output is included in Appendix O. These results indicate that it is possible to maintain the DO standard of 5 mg/L during the winter critical season.

The minimum DO of 5.1 mg/L was projected to occur in Lake Chicot (middle portion). In order for the model to predict a minimum DO of 5 mg/L, manmade NPS loadings were reduced. The manmade NPS loadings in the model were reduced by 50% to 100% in the four reaches that make up Lake Chicot. Plaquemines Alligator Farm effluent limitations were set to 10 mg/L BOD_5, 25 mg/L ammonia nitrogen, 12.5 mg/L organic nitrogen, and 5 mg/L DO.

No other reductions were needed in the system to meet the current DO standard of 5.0 mg/L.

4.3 Calculated TMDL, WLAs and LAs

TMDLs for the oxygen demanding constituents (CBODu, ammonia nitrogen, organic nitrogen, and SOD), have been calculated for the summer and winter projection runs. A summary of the loads is presented in Tables 4.2, 4.3, and 4.4. The loads presented in these tables represent the sum of the loads from all portions of the Bayou Cocodrie system that were modeled. The load from the CLECO generating facility was not counted as either point or nonpoint loading, since this facility just takes water out of Bayou Cocodrie, heats it up, cools it in Mountain Bayou Lake, and discharges it back to Bayou Cocodrie upstream of the intake. The TMDL calculations are shown in Appendix P.

Table 4.2. Total Maximum Daily Load for Bayou Cocodrie System for Current Criteria in the Summer.

	Oxygen demand (lbs/day) from:				Total oxygen demand (lbs/day)
	CBODu	Ammonia nitrogen	Organic nitrogen	SOD	
WLA for point sources	74	60	93	n.a.	228
MOS for point sources	19	16	25	n.a.	60
LA for manmade NPS	34858	0.0	0.0	729	35587
MOS for manmade NPS	3873	0.0	0.0	81	3954
LA for natural NPS	10924	4879	705	101562	118070
MOS for natural NPS	0	0	0	0	0
Total maximum daily load	49748	4955	823	102373	157899

Table 4.3. Total Maximum Daily Load for Bayou Cocodrie System for Proposed Criteria in the Summer.

	Oxygen demand (lbs/day) from:				Total oxygen demand (lbs/day)
	CBODu	Ammonia nitrogen	Organic nitrogen	SOD	
WLA for point sources	79	128	225	n.a.	432
MOS for point sources	21	33	59	n.a.	112
LA for manmade NPS	51857	0	22	3759	55638
MOS for manmade NPS	5762	0	2	418	6182
LA for natural NPS	11216	5092	729	109659	126696
MOS for natural NPS	0	0	0	0	0
Total maximum daily load	68934	5253	1037	113835	189059

Table 4.4. Total Maximum Daily Load for Bayou Cocodrie System for Winter.

	Oxygen demand (lbs/day) from:				Total oxygen demand (lbs/day)
	CBODu	Ammonia nitrogen	Organic nitrogen	SOD	
WLA for point sources	79	184	253	n.a.	516
MOS for point sources	21	47	66	n.a.	134
LA for manmade NPS	55018	237	52	2828	58135
MOS for manmade NPS	6113	26	6	314	6460
LA for natural NPS	11452	2256	808	51455	65971
MOS for natural NPS	0	0	0	0	0
Total maximum daily load	72683	2751	1184	54597	131215

5.0 SENSITIVITY ANALYSES

All modeling studies necessarily involve uncertainty and some degree of approximation. It is therefore of value to consider the sensitivity of the model output to changes in model coefficients, and in the hypothesized relationships among the parameters of the model. The QUAL-TX model allows multiple parameters to be varied with a single run. The model adjusts each parameter up or down by the percentage given in the input set. The rest of the parameters listed in the sensitivity section are held at their original projection value. Thus the sensitivity of each parameter is reviewed separately. A sensitivity analysis was performed on the proposed summer projection. The percent change of the model's minimum DO projections to these parameters is presented in Table 5.1. Each parameter was varied by ±30%, except for temperature, which was varied ±2ºC.

Values reported in Table 5.1 are sorted by percentage variation of minimum DO from largest percentage variation to smallest. Reaeration is the parameter to which DO is most sensitive (19% to 42%). The other parameters creating major variations in the minimum DO values are SOD (13% to 39%) and temperature (13% to 19%). The model results were slightly sensitive to depth and velocity with variations in predicted DO ranging from <1% to 12.9%. The model is not sensitive to headwater flow, CBOD decay, NBOD decay, or dispersion.

Table 5.1. Summary of Results of Sensitivity Analysis.

Input Parameter	Parameter Change	Predicted Minimum DO (mg/L)	Percent Change in Predicted DO
Baseline (summer projection run)		3.1	NA
Dispersion	– 30%	3.1	< 1%
Dispersion	+ 30%	3.1	< 1%
CBOD decay rate	– 30%	3.1	< 1%
Nitrification rate	+ 30%	3.1	< 1%
Headwater flow rate	– 30%	3.1	< 1%
CBOD decay rate	+ 30%	3.1	< 1%
Nitrification rate	– 30%	3.1	< 1%
Headwater flow rate	+ 30%	3.1	< 1%
Velocity	– 30%	2.7	13%
Depth	– 30%	3.0	3%
Velocity	+ 30%	3.4	10%
Depth	+ 30%	3.1	<1%
Temperature	– 2EC	3.5	13%
SOD	– 30%	3.5	13%
Temperature	+ 2EC	2.5	19%
Reaeration	+ 30%	3.7	19%
SOD	+ 30%	1.9	39%
Reaeration	– 30%	1.8	42%

6.0 CONCLUSIONS

Based on the modeling, maintaining the current summer water quality standard for DO requires a 100% reduction of manmade nonpoint sources and a reduction of background loads for Cocodrie Lake near the dam, Choctaw Bayou, most of Lake Chicot, and Bayou Cocodrie from just above the confluence of Bayou Chico to the mouth. The reduction of background loading cannot, of course, be implemented, indicating that the existing dissolved oxygen criteria are inappropriate for these waters.

In order to maintain the proposed summer water quality standard for DO the model requires significant reductions in the manmade nonpoint loading in Cocodrie Lake just above the dam and in several reaches of Bayou Cocodrie between river mile 26.8 and 16.8. The model also requires the elimination of all manmade loading in Choctaw Bayou and Lake Chicot. The implementation of this latter requirement may be difficult.

In order to meet the criteria in the winter, there must be reductions of the manmade nonpoint sources in Lake Chicot of up to 100%. Again, the implementation of this requirement may be difficult.

Reductions are needed at Plaquemines Alligator Farm for the summer and winter projections. Effluent limits must be reduced at Lake Chicot State Park WWTP in order to meet current standards in the summer. These reductions are detailed in Appendix P, and summarized in Table 6.1.

Table 6.1. Treatment Plant Upgrades and Manmade NPS Load Reductions Required to Meet DO Standards in Summer and Winter.

	City of Glenmora	Village of Forest Hill	Plaquemines Alligator Farm	Lake Chicot State Park WWTP	Manmade Nonpoint Source Loads		
					Bayou Cocodrie	**Cocodrie Lake**	**Bayou Chicot System**
Proposed summer criteria*	10/10/20/5.0	10/10/20/2.0	10/5.0/2.5/2.0	30/15/7.5/2.0	50% & 20% **	20%	100%
Current summer criteria*	10/2/4/6.0	10/10/20/2.0	10/5/2.5/6.0	10/10/5/5.0	100%	100%	100%
Winter criteria*	10/10/20/2.0	10/10/20/2.0	10/25/12.5/2.0	30/15/7.5/2.0	0%	0%	100%

* Point source effluent limits are expressed as BOD/NH_3N/Org-N/DO, percentages are averages
** Reductions needed in 2 reaches; most of Bayou Cocodrie required no reductions.

The proposed criteria having not been approved as of the date of this report, only allocations for the current criteria are currently appropriate for application.

Several other facilities were identified as being in the Cocodrie watershed but not having an impact on the model. These are included in nonpoint loading, or, in the case of the Town of Cheneyville, in the boundary loading for the Boeuf-Cocodrie Diversion Channel. These are listed in Table 6.2.

Table 6.2. Cocodrie watershed facilities not included in the model.

	St. Landry Parish School Board: Grand Prairie Elementary School STP	LIG Liquids: St. Landry NGL Plant	Cabot Corp: Ville Platte Carbon Black Plant	Town of Cheneyville POTW	LADOTD: Grand Prairie Rest Area STP
Permit No.	LAG540897	LA0005649 LAG480000	LA0001091	LA0059927	LAG540426 LA0093530
Outfall	001	002	002	001	001
UTM coordinates, NAD83 datum	581667E 3394989N	570820E 3412215N	571479E 3401727N	567834E 3429650N	584170E 3400071N
Discharge path	Ditch to small canal to unnamed stream to Bayou Cocodrie	Ditch to Bayou Cocodrie	Unnamed tributary to Bayou Petite Passe to unnamed diversion to Bayou Cocodrie to Boeuf-Cocodrie Diversion Canal	Agricultural drainage ditch to Boeuf-Cocodrie Diversion Canal	By ditch to unnamed lake to I-49 canal to an unnamed stream to Boeuf-Cocodrie Diversion Canal
Design or average flow	0.00596 mgd	0.00003 mgd	0.013 mgd	0.175 mgd	0.0131 mgd
Allocation	30 mg/l BOD5	30 mg/l BOD5	30 mg/l BOD5	CBOD (mg/l) 10 Apr-Oct & 20 Nov-Mar / NH3-N (mg/l) 2 Apr-Oct & 10 Nov-Mar / DO 5 mg/l	30 mg/l BOD5

LDEQ will work with other agencies such as local Soil Conservation Districts to implement agricultural best management practices in the watershed through the 319 programs. LDEQ will also continue to monitor the waters to determine whether standards are being attained.

In accordance with Section 106 of the federal Clean Water Act and under the authority of the Louisiana Environmental Quality Act, the LDEQ has established a comprehensive program for monitoring the quality of the state's surface waters. The LDEQ Surveillance Section collects surface water samples at various locations, utilizing appropriate sampling methods and procedures for ensuring the quality of the data collected. The objectives of the surface water monitoring program are to determine the quality of the state's surface waters, to develop a long-term data base for water quality trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program is used to develop the state s biennial 305(b) report (Water Quality Inventory) and the 303(d) list of impaired waters. This information is also utilized in establishing priorities for the LDEQ nonpoint source program.

The LDEQ has implemented a watershed approach to surface water quality monitoring. Through this approach, the entire state is sampled over a five-year cycle with two targeted basins sampled each year. Long-term trend monitoring sites at various locations on the larger rivers and Lake Pontchartrain are sampled throughout the five-year cycle. Sampling is conducted on a monthly basis or more frequently if necessary to yield at least 12 samples per site each year. Sampling sites are located where they are considered to be representative of the waterbody. Under the current monitoring schedule, targeted basins follow the TMDL priorities. In this manner, the first TMDLs will have been implemented by the time the first priority basins will be monitored again in the second five-year cycle. This will allow the LDEQ to determine whether there has been any improvement in water quality following implementation of the TMDLs. As the monitoring results are evaluated at the end of each year, waterbodies may be added to or removed from the 303(d) list. The sampling schedule for the first five-year cycle is shown below.

1999 - Calcasieu and Ouachita River Basins
2000 - Barataria and Terrebonne Basins
2001 - Lake Pontchartrain Basin and Pearl River Basin
2002 - Red and Sabine River Basins

Atchafalaya and Mississippi Rivers will be sampled continuously. Mermentau and Vermilion-Teche Basins will be sampled again in 2003.

7.0 REFERENCES

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8.0 APPENDICES

See attached Appendices A through P.